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## ATMOSPHERIC TURBULENCE


By O. G. Sutton, B.Sc.


In one of his books, Eddington speaks feelingly of the pure mathematician thrown into an irrational universe, but for whom " there will remain undisturbed a corner of knowledge where he may happily hunt for the roots of the Riemann Zeta function ". The parallel is not inapt for meteorology; in its broader aspects it does not take kindly to the bonds of mathematical thought, but the art of the mathematician does seem to have come into its own in that part of the subject which deals with conditions in the lowest layers of the atmosphere. Atmospheric turbulence has long provided a happy hunting ground for mathematical theorists, but in the last ten or fifteen years the concepts and methods of modern aerodynamical theory have wrought a profound change here with the result that there has been a spate of publications whose very number and variety might well cause a newcomer to pause in dismay. Meteorologists are now in the debt of Dr. Heinz Lettau, of Leipzig, who has undertaken the heavy task of bringing order to this chaos, and whose efforts have borne fruit in an attractively produced volume of some 300 pages*. It is a pleasure to record that Dr. Lettau has been largely

* " Atmosphärische Turbulenz " by Dr. Heinz Lettau. Med. 8vo., pp. XI + 283. Leipzig Akademische Verlagsgesellschaft M.B.H. 1939.


Victoria, B.C. ..... | 1016·1 | — 1·0 | 65 | 39 | 57·2 | 46·1 | 51·7 | + 1·4 | 47·9 | 76 | 6·6 | 2·61 | + 0·04 | 16 | 4·6 | 42

* For Indian stations a rain day is a day on which 0·1 in. or more rain has fallen.

successful in his task, and that there is now available a full and well written account of this fascinating branch of meteorology.

There is no exact mathematical definition of turbulent flow. The situation is perhaps best summed up in Oseen's dictum that a state of fluid motion is said to be turbulent when it is impossible to specify the details of the motion, and we have to be content with a knowledge of the mean flow. As far back as 1883, Osborne Reynolds, in a famous experiment, demonstrated the existence of two types of fluid motion, "laminar" and "turbulent", and he established for pipe flow a criterion for the generation of turbulence which gave rise to the "Reynolds' number", the basic parameter of aerodynamics. In the lower atmosphere, the wind is normally turbulent (i.e. consists of a series of gusts and lulls), but the degree of turbulence present fluctuates considerably, mainly due to the opposing effects of solar and terrestial radiation. Solar radiation promotes the generation of turbulence by day by setting up an unstable state in the lowest air layers, indicated by the presence of a high lapse rate; at night, turbulence tends to be damped out whenever the flow of outgoing radiation can cool the surface of the earth sufficiently to set up a large inversion of temperature gradient near the ground. This diurnal variation of turbulence is shown clearly by the records of the pressure tube anemometer, but if this were the only manifestation of eddies in the atmosphere, the gustiness of the wind would remain as a meteorological curiosity and little more. Turbulence, however, is the great atmospheric diffusing agency; anyone who has watched a weed fire in the country will have observed how rapidly the smoke is dispersed in the hours around noon, but on a clear evening, when turbulence is low, the smoke remains in the form of a thin ribbon which drifts away without any appreciable mixing. This effect is not confined to the diffusion of matter, for the upward spread of heat from the ground, resulting in the change of the amplitude and phase of the diurnal temperature wave with height, and the downward diffusion of

momentum replacing that absorbed by the drag of the ground, and which reveals itself in the form of the velocity-height curve, are chiefly due to the eddying of the wind. It is perhaps not immediately obvious how much civilized life depends on this steady churning of the lower atmosphere, but without it the great cities and industrial areas of the world could not be inhabited except by a race living perpetually in gas masks. Let the turbulence of the air near large factories fall for a few days, and we have the situation which developed near Liege, Belgium, in 1930, when, in an abnormally calm period, many deaths resulted from the inhalation of industrial smoke hitherto regarded as innocuous. Evaporation, the distribution of pollen and the lighter seeds, all depend on this enhanced diffusion in the air, so that man does not merely live in a turbulent atmosphere—his very life depends on it!

To appreciate the changes which have appeared in the treatment of atmospheric turbulence in the last decade, it is necessary to interpolate here some remarks on modern aerodynamical theory. The classical hydrodynamics can claim a fair measure of success in predicting the lift of an aerofoil, but the problem of the drag (i.e., resistance), of a body placed in a viscous fluid presented almost insuperable difficulties which were somewhat mitigated by Prandtl's introduction of the concept of the *boundary layer* in 1904. This theory, in brief, postulates that the resistance of a body is largely determined by what happens in a thin layer of fluid near the surface, where inertia and viscous forces are of comparable magnitude. This concept has proved extraordinarily fruitful, and may be said to be at the heart of modern aerodynamics, but in dealing with anything except very low velocities it is necessary to distinguish between two possible types of boundary layer, namely, the " laminar layer " in which the flow may be slightly undulatory but is non-turbulent, and the " turbulent boundary layer ", of much greater thickness, and having very different characteristics, particularly as regards velocity distribution. For smooth surfaces, the turbulent boundary

layer envelops a very shallow surface layer, termed the " laminar sub layer ", in which the flow is again non-turbulent. The calculation of the drag of a plate is then possible if the velocity profile (i.e., the shape of the velocity-height curve) is known throughout the boundary layers.

But, it may be objected, why should the meteorologist, whose concern is with the properties of the atmosphere, trouble himself with the niceties of the calculation of skin friction? The relevancy arises from the fact that the resistance offered by the plate shows itself in the curvature of the velocity profile near the surface, for the drag is, in effect, a measure of the rate at which momentum is being absorbed from the stream. To keep matters steady, there must be a continual downward flow of momentum, brought about by an exchange of air masses in the vertical, i.e., by turbulence. Such an exchange must simultaneously cause a transfer of heat and mass, so that a knowledge of the mechanism of momentum transfer is bound to yield information on such apparently dissimilar matters as the cooling of a hot body, or the removal of vapour from a moist surface. Thus we have to consider, in addition, temperature and mass boundary layers. The turbulent boundary layer theory has yielded remarkable results in the hands of Prandtl, von Kármán and their associates, but it must be realised that much of their work is of an empirical or tentative nature. There is still no wholly satisfactory theory of turbulence, even for the relatively simple cases outlined above.

In the atmosphere, conditions are more complex. The boundary layers referred to above start at the leading edge of the plate, and form a kind of a blanket over the surface, increasing in depth with distance downwind according to certain well established laws. For atmospheric flow, it is necessary to distinguish between small scale phenomena, where the surface under investigation may be looked upon as developing its own relatively shallow boundary layer, and phenomena which take

place in the boundary layer of the earth itself. Evaporation from a small sheet of water, or the diffusion of smoke from a factory can be regarded as belonging to the former class, whilst the approach of the surface wind to the gradient wind is typical of phenomena controlled by the permanent boundary layer (some 2,000 feet deep) of the earth's atmosphere, and which is termed by Lettau the " planetary boundary layer ".

In the kinetic theory of gases, diffusion, conduction of heat and viscosity are explained as the inevitable effects of the random motion of the molecules, and the earlier attempts to treat both the large and small scale problems of atmospheric turbulence were founded on a supposed analogy between molecules and eddies as transport agents. The pioneer development of this theory was carried out more or less simultaneously by Schmidt, in Austria, and by Taylor and Richardson in this country. Taylor, in particular, was successful in devising a theory of vorticity transport, having its roots in the classical hydrodynamics, which gave good agreement with observations on such diverse aspects as the slowing down of the gradient wind by the drag of the earth's surface, and the temperature distribution in the fogs of the Grand Banks. For the most part however, the work of this period consisted largely in applying the classical equations of diffusion, heat conduction and viscous motion to the problems of turbulence with little or no change, the difference between molecular and eddy phenomenon being assumed to be in the order of magnitude of the corresponding coefficients. This simple theory failed completely to account for the details of the observations, particularly those made near the ground. In the kinetic theory of gases the value of the diffusion coefficient depends, among other things, on the length of the mean free path of the molecules, and Prandtl, in 1925, introduced for turbulent fluids the concept of a " mixing length " (*Mischungsweg*), analogous to the molecular free path, but with the vital difference that the mixing length depends upon the position of the reference point with respect to the boundary. Later, von Kármán was

able to show that (for pipe flow at least) the nature of turbulent mixing is determined by the characteristics of the mean flow at the given point—in other words, the mixing length depends essentially on the spatial derivatives of the mean velocity. It is not possible here to enter further into discussion of this theory, which in the hands of the Göttingen mathematicians has become one of the outstanding successes of modern fluid motion theory, and the reader who is anxious to know more will find an excellent introduction to the subject in Dr. Lettau's book.

Pipe flow is, however, relatively simple compared with the movement of air over the earth's surface. The meteorologist, seeking to apply the above ideas to his problems, finds himself in difficulties at once, mainly owing to two factors, the roughness of the ground (due to obstacles of such varying magnitude as grass, trees, houses and hills), and the ever changing stability of the flow, as indicated by the vertical gradient of temperature near the ground. Nevertheless, considerable progress has been made towards the solution of the difficult problems presented by these factors. The effects of surface roughness and stability have been investigated by Rossby, Sverdrup and Paeschke, with encouraging results, whilst the present reviewer has been able to show how the rate of evaporation from a free liquid surface is intimately linked with the vertical gradient of wind velocity, and thence with the degree of turbulence in the atmosphere. Speaking broadly, it may be said that there is now a considerable body of knowledge relating to the development of the mass and momentum boundary layers at the surface of the earth.

Dr. Lettau has given a clear and interesting account of the large scale phenomena taking place in the planetary boundary layer, but it is somewhat disappointing to find little prominence given to Taylor's vorticity theory and its application to the problem of the approach to the gradient wind. This still remains as one of the most striking and satisfactory investigations ever made in meteorology, and the vorticity transport theory is to this

day in some respects superior to the later momentum transport theory of the German school. The problem of the propagation of the diurnal temperature wave through the atmosphere still awaits a satisfactory solution, but here the situation is complicated (perhaps hopelessly) by variations in the stability of the air motion and by the effects of radiation.

The function of turbulence as a diffusing agent is perhaps, to the meteorologist, its chief interest, but there is a vast field of research open to the investigator on wind structure, a matter of prime importance to the airman. It is impossible here to deal adequately with this aspect, which covers such matters as soaring flight (" dynamical " soaring, for example, as opposed to " thermal " soaring, is only possible in a fluctuating wind), and the disaster to the airship R.101, or with turbulence as it affects the dissipation of energy in the atmosphere. Having covered, at least in some part, almost every theoretical aspect of his subject, Dr. Lettau has not forgotten that the bulk of meteorological observations are taken well inside the earth's turbulent boundary layer, and has devoted a chapter to meteorological instruments. Meteorologists are normally interested in mean values only, and these at one level, but the present reviewer would like to put forward a plea for more measurements of the gradients of wind and temperature near the surface. These are the raw material out of which the theory of atmospheric turbulence must ultimately shape itself towards its final perfection.

## RADIOMETRIC SCALES

By D. N. Harrison

The radiometers used for meteorological purposes measure intensity of radiation either from the sun alone or from the sun and sky, the units commonly employed being milliwatts per sq. cm. or calories per sq. cm. per minute. They cannot be regarded, however, as absolute instruments, but have to be calibrated by comparison with some standard designed to reproduce the absolute scale of intensity. From time to time various instruments, absorbing and measuring the incident radiation in various ways, have been produced and used as standards. It is difficult to make an instrument which will give an absolute measure of intensity within one per cent. and it is therefore important to know how the standards compare with one another and how accurately they realise the true scale. Since they are in different countries, they have to be compared by means of substandards.

A recent paper by J. Guild* describes two new absolute radiometers made at the National Physical Laboratory and the results of comparisons between these and certain well-known standards.

The principle of the new instruments is as follows: Two thick copper discs are placed 1 cm. apart and connected by seven pieces of eureka wire soldered to their inner faces; a copper lead is also soldered to each disc. This arrangement constitutes seven thermocouples in parallel, and the E.M.F. will depend on the mean difference of temperature of the discs. To the outer face of one disc is cemented an insulated grid through which a current can be passed; this face is smoked black and exposed to the radiation. The rise in a given time of the temperature of this disc, as indicated by the thermo-electric current, is used to compare the energy absorbed from the radiation with that absorbed from the grid when a measured current is passed through it. These being

* London, *Proc. roy. Soc.* (A) No. 904, 161, pp. 1–38 (July, 1937).

made practically equal, the method becomes one of substitution, and the result does not depend on the properties of the indicating system.

In order to test the effect of the difference between the paths of the heat absorbed from the radiation and the heat generated electrically, the grids of the two instruments were made different, in such a way that one was expected to over-estimate and the other to under-estimate the intensity of radiation. The two instruments agreed to within one part in a thousand: therefore there could be no significant systematic error from this cause.

These instruments also agreed within one part in a thousand with the N.P.L. standard, an improved Callendar radio-balance. Since the radio-balance differs widely in principle and mode of operation from the new radiometers, the agreement is strong evidence of the absolute accuracy of both types.

Other instruments tested were: (1) the lamp standardised by Callendar and used as a source of radiation for the calibration of radiometers, (2) several standard lamps issued by the National Bureau of Standards of Washington, (3) an Abbot silver-disc pyrheliometer calibrated on the Smithsonian scale, and (4) an Angström pyrheliometer. The results were:

(1) Callendar's scale agrees with the N.P.L. scale within $\pm$ 5 parts in a thousand.

(2) The N.B.S. scale agrees with the N.P.L. within $\pm$ 2 parts in a thousand.

(3) The error of 2·3 per cent. over-estimation, found by the Smithsonian workers for their own scale, was confirmed to within one part in a thousand.

(4) The Angström scale under-estimates radiation by 5 parts in a thousand.

An important point brought out in Guild's paper is that a pyrheliometer may not read correctly on the scale on which it was calibrated if the angular distribution of intensity of the radiation received is different for calibration and for observation. For instance, it is concluded that part of the difference found by other workers between the Abbot and Angström instruments, when

used for solar observations, was due to the larger amount of skylight taken in by the Abbot. In discussing comparisons of the high accuracy now attainable it has also to be remembered that there is a certain probability of error in the calibration of the substandard instruments which must necessarily be used in any such comparison. The paper includes a valuable discussion of sources of error and of the methods adopted to ensure strict comparability in the readings of instruments of different types.

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## CAUSE AND EFFECT

By A. F. Crossley

During the Monday evening discussion at the Meteorological Office on November 28th, 1938, I referred to a published statement by Dr. H. Jeffreys to the effect that if two related events occur simultaneously, then neither can be the cause of the other, but both may usually be traced to some cause earlier than either. As the truth of this statement was received doubtfully at the time, and as the question is of some importance in meteorology it may be desirable to reproduce a passage from Jeffreys' argument in his book "Scientific Inference" (Cambridge 1931, pp. 209–212). The passage which is of most interest in this connexion concerns the use of the words *cause*, *effect*, and *because* (p. 211). "If a scientific law involves a number of variables, then a knowledge of all but one of them determines that one. We say that it has a certain value *because* the others have certain values. The notions of cause and effect involve rather more than this; there is an asymmetry about them that is absent from the word *because*. Thus we may say either that a triangle has the angles at the base equal because it is isosceles, or that it is isosceles because the angles at the base are equal. When we speak of a cause and an effect, we pick out the one as the cause and the other as the effect, and they cannot be interchanged. The distinction seems to

be one of time; the events under discussion are connected by a scientific law, and we pick out the earlier and call it the cause, and the later the effect. There is no distinction of cause and effect for contemporaneous events ".

In meteorology one is concerned among other things with the relation between pressure and wind. It is to be noted however that a meteorological situation in which there is no horizontal temperature gradient is a special case which results when the potential energy of previous temperature inequalities has been converted wholly or partly into kinetic energy. In this special case, pressure and wind are interchangeable in the sense mentioned by Jeffreys; there is a relation between them which ensures that knowledge of either determines the other, and it is clear that neither can be cited as the cause of the other.

It follows that in any discussion of cause and effect in meteorological hydrodynamics, temperature differences (present or past) must be taken into account. The position of temperature can be illustrated by considering motion starting from rest (or change of motion from an initially steady state). Suppose there is no horizontal temperature gradient initially, but that one is produced by absorption of more heat in some places than in others. One commonly introduces in explanation of the consequences a spurious time-order of events. Thus it is supposed that the air at first expands vertically, leaving the surface pressure unchanged, while at other levels the isobaric surfaces become inclined and so produce a flow of air which, again, produces variations in the surface pressure—and so on, the various effects interacting on one another more and more. In point of fact, however, this interaction must exist right from the beginning. Absorption of heat, the related pressure gradients and wind must all come into existence simultaneously, a fact which is necessarily made use of in the statement of any equations of motion. At any time from the initial instant, knowledge of the distribution of any two of pressure, wind and temperature suffice to determine the

the third, at least in theory. The three events play interchangeable parts and occur simultaneously, so that no one of them can be singled out as a cause of the other two.

The quest for a cause then takes us back a stage further to the method by which the heat is introduced. The only method of transference which does not itself depend on variations in the atmosphere previously produced is by radiation from the sun, and this is seen also to be the only relevant event definitely earlier in time than the related temperature, pressure and wind variations. Hence we conclude that solar radiation is the only cause, in the true sense of the word, of the subsequent variations of temperature, pressure and wind.

It was also urged against my remark at the discussion that it obviously broke down when applied to force and acceleration, since force is certainly the cause of acceleration, but the two events nevertheless occur simultaneously. The catch here lies in the assumption that two events are involved. The relationship between force and acceleration is of a more intimate kind than that, e.g., which gives the connexion between pressure and wind; these two are entirely distinct events connected by a known physical law. The equation $P = mf$ on the other hand is no more than a definition which makes it possible to measure force in terms of acceleration; force cannot in fact be measured in any other way, but we do not have to read the barometer before we can find what the wind is, or vice versa. Force and acceleration cannot therefore be regarded as separate events, but only as two aspects of the same event, and no cause-effect relationship between them can arise.

This is not the first time that this subject has been considered in this magazine. An earlier discussion was started by Sir Napier Shaw in the issue for October, 1930, and continued by him and by me in February, 1931.

## LETTERS TO THE EDITOR

### A Rare Halo Phenomenon, March 31st, 1939

The following note may be of interest. At 12h. 30m. (G.M.T.) on March 31st, 1939, a faint halo of about 22° was present with the addition of a brilliant circumscribed upper arc of contact. Each end of the latter

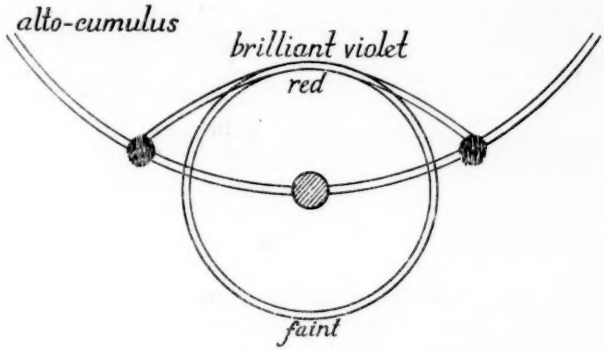


FIG. 1.—HALO SYSTEM OBSERVED AT HASTINGS, MARCH 31ST, 1939, 12H. 30M., G.M.T.

terminated in a parhelion, and through these and the sun passed a large segment of the parhelic circle. It was particularly noticed that the latter extended inside the ordinary halo, right up to the sun which was sufficiently obscured to render observation with the naked eye practicable. By holding up a card so that it obscured the sun completely the parhelic circle was even more plainly visible in close proximity to the former. The whole phenomenon did not last long after 12h. 30m. and had completely faded by 13h.

A. E. MOON.

*39, Clive Avenue, Clive Vale, Hastings.*
*April 3rd, 1939.*

## A Double Rainbow

On the evening of April 24th, 1939, at 18h. G.M.T., during a heavy shower, there was one of the most brilliant rainbows I have witnessed. Both primary and secondary were complete. The primary was narrow and the colours distinct and brilliant red, orange, yellow, green, indigo, violet. At the crown of the arch were two or three green and purple spurious bows. In view of discussions as to the position of the bow it is interesting to note that to me one end of the bow appeared to be in front of the landscape and to terminate about 150 yards away.

CICELY M. BOTLEY.

*Guildables, 17, Holmesdale Gardens, Hastings.*
*April 24th, 1939.*

## Lunar Rainbows

Mr. Davies' interesting article on Lunar Rainbows in the March issue of this magazine prompts me to write of my experiences of lunar rainbows, especially as the meteorological conditions under which they are occasionally seen here are quite different to those referred to by Mr. Davies.

I live on the eastern border of Dartmoor and lunar rainbows are sometimes seen here in the warm sector of a depression. Given a strong westerly wind with thick orographic drizzle over Dartmoor, a break in the low stratus clouds often occurs just to the lee of Dartmoor. This local break in the clouds (about 4 to 5 tenths of blue sky can be seen) often persists for some hours, and at the same time the drizzle over Dartmoor is blown over us. Thus the presence of a bright moon shining through this break produces a lunar rainbow. In the five years that I have lived here I have observed four such rainbows. All the rainbows were quite distinct, but no colours could be seen, the bows appearing white. One of these rainbows lasted for two hours.

It might be added that solar rainbows under these conditions are fairly common and on one occasion a rainbow was seen for five hours continuously.

No doubt others living on the lee side of large hill masses experience the same.

G. B. DAVIE.

*North Harton Farm, Lustleigh, Devon.*
*March 25th, 1939.*

## Height Calculation from the Emagram

Dr. R. C. Sutcliffe(1) gave an easy rule for finding the approximate height from the tephigram. The following method corresponding with Sutcliffe's process provides

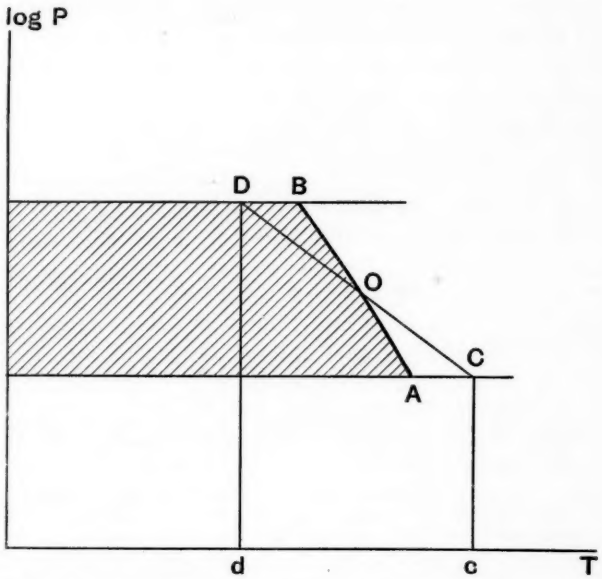


FIG. 1.—HEIGHT CALCULATION FROM THE EMAGRAM.

a very simple and theoretically accurate method of measuring height from the emagram with generality. One of the properties of the emagram noted by the

present author(2) is that geodynamic height is equal to R (gas constant) times the area. If, in Fig. 1, showing a portion of the emagram, A and B are two points on a curve representing an upper air sounding, then the geodynamic height difference between them is given by the shaded area bounded by the curve AB and the two isobars through A and B continued down to the absolute zero of temperature. If now we draw between the same two isobars an adiabatic line CD cutting the curve at O in such a position that the area COA = DOB then, plainly, by the above proposition, the height between A and B is equal to the height of the isentropic atmosphere CD. But the temperature range must be multiplied by 102 to give heights of an isentropic atmosphere in metres. Furthermore, the temperature scale on the tephigram is uniform and the height interval AB is represented simply and directly by the length of the line cd.

In the case of the damp air, the virtual temperature instead of the temperature itself should be used.

I think this method of interpreting Stüve's formula makes the reason simpler and clearer than Stüve's(3) or Harrison's(4) interpretation of it.

H. ARAKAWA.

*Tokyo.*
*March, 1939.*

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(1) R. C. Sutcliffe. "Height calculation from the tephigram—another simple method". *Met. Mag., London,* 73, 1939, pp. 336–337.

(2) H. Arakawa. "Höhenberechnungen und energetische Betrachtungen mittels Emagramm". *Leipzig, Beitr. Geophys.*, 51, 1937, pp. 321–324.

(3) G. Stüve. "Aerologische Untersuchungen zum Zwecke der Wetterdiagnose, Die Arbeiten des Preussischen Aeronautischen Observatoriums bei Lindenberg". *Braunschweig, Arb. preuss. aero. Obs.* XIV, 1922, pp. 104–116.

(4) Louis P. Harrison. "Mathematical Theory of the Graphical Evaluation of Meteorograph Soundings by Means of the Stüve (Lindenberg) Adiabatic Chart". *Mon. Weath. Rev., Washington,* 63, 1935, pp. 123–135.

## The Winter's Snowfall in the Chiltern Hills

In the March issue of this magazine Mr. Bonacina quoted my estimate that the deepest of the snowdrifts left on the Chiltern Hills by the blizzard of January 25th to 27th, 1939, were likely to linger into March. Though unable to produce evidence that any of them did so, I can vouch for this much: in spite of 108 hours of sunshine and screen maximum temperatures of 50° F. to 55° F. on seven days during February at the Whipsnade Park climatological station, the final traces of one drift which was initially some 15 ft. deep did not disappear from Bison Hill (700–750 ft. above M.S.L.) until the morning of February 28th.

The 48-hour snowstorm of January, 1939, is said by old folk hereabouts to have rivalled in severity any experienced since January, 1881. A number of motor-cars, lorries and tractors were buried for several days, and at one point a double-decker omnibus was almost completely engulfed. In my grounds (550–600 ft. above M.S.L.) 25 measurements gave 15·5 in. as the average depth of snow over three acres at 9h. on January 27th. This was exceeded by 2·5 in. on December 26th, 1938, after a week's intermittent fall, but the drifting was not then so great as in the later storm. It may be of interest to add that out of the 73 days from December 18th, 1938, to February 28th, 1939, there were not more than twelve on which Dunstable Downs were free from either a snow-cover or patches of snow. According to my records, kept on the eastward-facing hillside above Dagnall, the integrated depth of all the numerous falls during the last fortnight of December and the period January 1st to 29th was of the order of 45 in.

E. L. HAWKE.

*Ivinglea, Dagnall, Bucks.*
*April 1st, 1939.*

## NOTES AND NEWS

*High-Altitude Records from the Northern Pennines, 1938–39.*

In the April, 1938, issue of this magazine, a summary was given of the temperatures recorded during 1937 at Moor House, Upper Teesdale (1,840 ft.), and of those recorded during the winter at the nearby mountain-top station on Dun Fell (revised altitude, screen, 2,735 ft.). The latter station has been set up by the writer in connexion with the investigation of the " helm wind ", and a preliminary summary of results has been published in *Nature* (March 4th, 1939, p. 377).

TABLE I.—MOOR HOUSE (1,840 FT.).

| 1938. | Temperature. | | | | | Rainfall. |
|---|---|---|---|---|---|---|
| | Mean. | Mean Max. | Mean Min. | Extremes and Dates. | | |
| | °F. | °F. | °F. | °F. | °F. | inches. |
| Jan. .. .. | 35·2 | 38·3 | 32·1 | 46 (23) | 17 (10) | 10·73 |
| Feb. .. .. | 34·7 | 38·3 | 31·1 | 47 (26) | 23 (22) | 4·36 |
| Mar. .. .. | 42·1 | 46·5 | 37·7 | 54 (13) | 27 (26) | 5·66 |
| Apr. .. .. | 39·0 | 46·4 | 31·6 | 59 (12) | 23 (17) | 2·28 |
| May .. .. | 42·8 | 50·2 | 35·5 | 59 (21) (22) | 19 (8) | 4·35 |
| June .. .. | 49·1 | 55·7 | 42·5 | 71 (17) | 35 (23) | 7·38 |
| July .. .. | 51·6 | 58·2 | 45·0 | 68 (23) | 32 (5) | 8·37 |
| Aug. .. .. | 52·5 | 60·2 | 44·8 | 73 (10) | 32 (31) | 6·51 |
| Sept. .. .. | 48·9 | 54·7 | 43·1 | 63 (26) | 34 (15) | 3·91 |
| Oct. .. .. | 43·5 | 47·8 | 39·3 | 55 (1) | 32 (29) | 19·41 |
| Nov. .. .. | 41·3 | 44·6 | 38·0 | 55 (13) | 28 (22) | 9·66 |
| Dec. .. .. | 33·8 | 36·9 | 30·7 | 46 (13) | 16 (20) | 9·43 |
| 1939. | | | | | | |
| Jan. .. .. | 30·8 | 34·6 | 27·0 | 43 (8) | 9 (4) | 10·52 |
| Feb. .. .. | 35·6 | 39·1 | 32·1 | 48 (9) | 12 (2) | 9·21 |
| Mar. .. .. | 35·5 | 39·6 | 31·8 | 47 (3) (16) | 27 (9) | 5·98 |

At Moor House, which has now been in operation for seven years, new low records were set up with regard to minimum temperatures in May (18·5° F.) and July

(31·5° F.) while October was almost free from frost in the screen. The lowest maximum temperature, 23° F. on December 20th, was not quite as low as that recorded at several stations in south-east England. The year was excessively wet; rainfall in October was particularly heavy. At the same time the year was exceptionally free from snow; snow-cover was only recorded on approximately 30 days, and the road to the house was not blocked for more than two weeks in the year.

On Dun Fell, three miles west of Moor House, a continuous record has been maintained throughout all

TABLE II.—DUN FELL (2,735 FT.).

| 1938. | Temperature. | | | | | Snow-Cover (Approx. No. of Days). |
|---|---|---|---|---|---|---|
| | Mean. | Mean Max. | Mean Min. | Extremes and Dates. | | |
| | °F. | °F. | °F. | °F. | °F. | |
| Jan. .. .. | 31·9 | 34·8 | 29·0 | 43 (22) | 23 (27) | 17 |
| Feb. .. .. | 30·6 | 34·1 | 27·1 | 44 (26) | 20 (11) (15) | 13 |
| Mar. .. .. | 38·0 | 41·5 | 34·5 | 49 (11) | 23 (26) | 2 |
| Apr. .. .. | 36·2 | 42·2 | 30·2 | 55 (13) | 21 (17) | 3 |
| May .. .. | 39·7 | 45·8 | 33·6 | 55 (22) | 23 (8) | — |
| June .. .. | 45·2 | 50·1 | 40·3 | 64 (17) | 33 (2) | — |
| July .. .. | 47·5 | 51·9 | 43·2 | 62 (23) | 36 (5) | — |
| Aug. .. .. | 51·0 | 56·7 | 45·4 | 69 (10) | 36 (20) | — |
| Sept. .. .. | 47·0 | 51·5 | 42·5 | 63 (10) | 33 (15) | — |
| Oct. .. .. | 40·4 | 44·3 | 36·5 | 52 (1) (13) | 29 (27) | 1 |
| Nov. .. .. | 38·0 | 40·9 | 35·0 | 51 (12) (13) | 24 (22) | 14 |
| Dec. .. .. | 30·3 | 33·3 | 27·3 | 43 (14) | 12 (20) | 17 |
| 1939. | | | | | | |
| Jan. .. .. | 28·7 | 31·5 | 26·0 | 41 (15) | 17 (4) | 21 |
| Feb. .. .. | 32·0 | 35·1 | 28·9 | 45 (8) | 20 (3) | 15 |
| Mar. .. .. | 31·1 | 34·5 | 27·7 | 43 (3) | 23 (27) | 18 |

but a few days. At this altitude conditions are liable to be very severe in winter, and no method has been found of ensuring that the instruments in the screen are always

kept free from snow. It appears that if the temperature is below about 27° F. during snowfall the snow will not accumulate in the screen, but almost every fall has occurred with temperature higher than this. Five examples of observations made during visits may be cited as an indication of prevailing weather conditions:—

January 29th, 16h., 24° F., wind E 9, cloudy, surface-drift of snow.
May 1st, 7h., 30° F., wind NE 8, fog with rime-deposit.
July 10th, 9h., 43° F., wind W 5, fog.
August 26th, 15h., 55° F., wind W 2, cloudy.
November 19th, 14h., 33° F., wind WSW 8, c PRS.

From November to early March the apparent daily range of temperature is very largely an expression of irregular variations due to the advent of differing supplies of air. After March the diminishing amount of low cloud, in combination with the increased power of the sun, gives a much more regular daily variation. The spring and autumn "lag" of temperature, characteristic of mountain stations, was strongly marked in 1938. While persistent low temperatures occurred in May, August, September and nearly four weeks in October were all free from frost on the summit, during which months lowland stations in the Eden Valley suffered. The tendency for minima to occur soon after sunset, characteristic of summit stations, is well marked in quiet weather. Under similar conditions in the valley below, the evening katabatic wind ("the fell wind") is sufficiently regular to be regarded locally as an augury of a fine day to follow.

As a whole the Dun Fell summit station reproduces the characteristics of Moor House in exaggerated degree. The frequency with which winter temperatures remain persistently close to the freezing-point, accompanied by strong wind, is notable. The difference of altitude, 900 ft., was sufficient to result in a snow-cover on the summit for 64 to 67 days, against 30 at Moor House. The lowest maximum, 18° F., and minimum, 12° F., both occurred on December 20th. One may also comment on a maximum of 37° F. on June 2nd, after sleet. During August 5th to 12th lowland inversions were

particularly well developed at night, and the temperature did not fall below 51° F. on the summit. The highest for the year was 69° F., on August 10th; temperature exceeded 60° F. on sixteen days, and touched 32° F. or lower on 138 days, in a mild year.

The means given in the tables refer throughout to the period 0h. to 24h. It may be of interest to point out that a third station in a well-exposed situation has been maintained at Milburn Grange (675 ft.) at the foot of the Crossfell escarpment immediately below Dun Fell. This station and Newton Rigg are however in close accord; it is abundantly clear that the Eden valley between them, e.g. at Appleby, frequently forms a notable frost-hollow.

Acknowledgments are due to the Leverhulme Trustees, and to the Council of the Durham Colleges, for grants-in-aid.

GORDON MANLEY.

*Cumulus Cloud formed by Smoke Column*

An interesting example of the development of cumulus cloud from a smoke column was observed at Wittering between 10h. 30m. and 12h. on November 15th, 1938. Shortly after 10h. 30m. a thin smoke column was noticed to be rising straight up some distance to west-north-west of the aerodrome. It is possible the smoke may have been from a quarry some three miles distant (the quarry is not visible from Wittering).

At an estimated height of between 1,000 to 1,500 ft. the smoke spread out into a long plume across the western sector of the sky and there was a small extension towards north-west. By 10h. 45m. the smoke column increased in intensity and a small bulge began to form in the smoke streamer above this column. Very slowly during the next 15 minutes this bulge increased in size and assumed a dome shape. A short while after 11h. the smoke column thickened considerably and the dome shaped cloud which had formed at its top began to grow rapidly in size. It is estimated that by 11h. 30m. the top of the cloud was between 2,500 and 3,000 ft. with base about 1,200 ft. The cloud was similar to large cumulus but had a soft appearance and so far as could

be seen showed no tendency to break up or disperse. The " cauliflower " top was apparent but was quite soft and woolly. Owing to distance it was not possible to observe fully the turbulence effects but it could be seen that the upper part of the cloud was continually changing its shape.

By 12h. the intensity of the smoke column diminished considerably and the cloud began to disperse. There was little actual movement or rapid breaking up into fragments, the effect was rather a more gradual dissolution from the summit downwards, but portions of the base broke up and began to drift slowly away. These portions, however, disappeared very quickly when but a short distance from the cloud. Between 10h. and 12h. the surface conditions were:—

*Wind.*—Generally calm, but occasional light puffs from a south-easterly point.
*Weather.*—Hazy, visibility varying 3,000 yards to 5 miles.
*Cloud.*—A trace of small cumulus cloud in the south-west.

W. F. WATSON.

*Royal Meteorological Society.*

The usual monthly meeting of the Society was held on Wednesday, April 19th, in the Society's rooms at 49, Cromwell Road, South Kensington. Dr. B. A. Keen, F.R.S., President, was in the Chair.

Prof. E. J. Salisbury, D.Sc., F.R.S., delivered the Symons Memorial Lecture on the subject of " Ecological aspects of meteorology ". The lecturer described first the relative importance of extreme and mean climatic conditions from the point of view of their influence upon the persistence of species, and the biological significance of summations of temperature. He referred to the importance of absolute minima, even when infrequently paralleled, in influencing geographical distribution, the relation of frost severity to the survival of " winter annuals " and " summer annuals ", and the effect of maximum temperatures on the production of flower and seed. Another meteorological condition to which he referred was the nature of the soil surface and its effect on air temperatures, and he pointed out that the influence

of meteorological conditions upon plant life is modified by the biology of the species.

Among the meteorological factors discussed were:— The importance of katabatic winds on plant life by the modifications of temperature which they bring about; the effect of duration and intensity of sunshine on reproduction and the phenomenon of " photoperiodism "; the role of precipitation as a source of raw material, an agent in erosion and in leaching the soil, and the significance to plant life of the seasonal incidence and intensity of precipitation.

It was remarked that meteorological factors also influence the development of soils, that they are in turn modified by the plant covering and that wind is another ecological factor, producing both direct and indirect effects. Finally the lecturer discussed the influence of meteorological factors on the conditions of life in a changing plant community, and illustrated his remarks by reference to dune soils.

At the meeting on April 26th, 1939, the President took the Chair and Major H. C. Gunton presented the Phenological Report for 1938.

*Severe thunderstorms on May 19th, 1251.*

Matthew Paris gives the following account:—

About the same time of the year, that is, in summer on the day of St. Dunstan, a thick cloud arose in the morning over the whole world, as it seemed, darkening east as well as west, south as well as north, and thunder was heard as if at a great distance, with lightning preceding it. And about the hour of prime, the thunder and lightning approached, one clap being more terrible than the others, as if the sky bore down on the earth, the ears and hearts of all who heard being suddenly struck dumb. With that crash a thunderbolt fell upon the queen's bedroom, where she was then staying with her sons and family, and crashing the fireplace to powder, threw it to the ground and shook the whole house. And in the neighbouring forest, namely that of Windsor,

35 oaks were thrown down or split asunder. In addition, certain mills with their millers, and sheep pens with their shepherds and several farmers and travellers were crushed. And much damage was inflicted upon mortals such that we who write this have not seen nor heard before. At St. Albans also lightning fell upon a washing place in that monastery but not much damage was done: but traces appeared in the wall for many years after.

C. E. BRITTON.

*Sunshine, April,* 1939.

The distribution of bright sunshine for the month was as follows:—

| | Total hrs. | Diff. from average hrs. | | Total hrs. | Diff. from average hrs. |
|---|---|---|---|---|---|
| Stornoway .. | 174 | +24 | Chester .. | 161 | +22 |
| Aberdeen .. | 149 | + 5 | Ross-on-Wye | 177 | +35 |
| Dublin .. | 179 | +20 | Falmouth .. | 207 | +20 |
| Birr Castle .. | 169 | +17 | Gorleston .. | 182 | +18 |
| Valentia .. | 177 | +16 | Kew.. .. | 174 | +28 |

Kew temperature, mean, 49·1° F.: diff. from average, +1·4° F.

## REVIEWS

*The Admiralty Weather Manual, 1938.* $9\frac{1}{2} \times 5\frac{3}{4}$, pp. 496 *illus.*, H.M. Stationery Office, 1938. Price 10*s.* 6*d. net.*

Before 1914 meteorology was purely a science of civil life. Meteorologists could advise the farmer when to cut his hay, or the skipper of a fishing vessel when not to leave harbour, while facilities were available for issuing forecasts to the general public, but the military mind had apparently failed to realise the strategic importance of a pre-knowledge of weather. There had been famous occasions when weather changed the course of history,

but for sixty years British campaigns had been fought in distant climatically stable regions and history was forgotten. In 1914 a meteorological organization had to be improvised in the field, but the lesson, driven home by the coming of the aeroplane, was well and truly learnt. Meteorology, and trained meteorologists, now form an integral part of our defence plans. But scientific training requires text-books, and where the purpose of the training is highly technical, the books must be specially written. The problems of the Navy, both afloat and in the air, are not the same as those of the forces operating from land bases, and so the Admiralty Weather Manual has been written for the use of naval meteorological officers.

The book is very thorough. It is divided into three sections, dealing respectively with meteorological instruments and observations, general meteorology, and synoptic meteorology. Most of the instruments are common to land and sea, but accurate observations on or from a moving ship require special adaptations which are described at length in the first chapter. This and the second chapter on non-instrumental observations and the coding of messages call for little remark. Velocities are expressed in knots even in the free air, and distances on the visibility scale in cables and miles, but even if the latter are " sea " miles equating one mile to two kilometres surely exceeds the limits of tolerance. The last two chapters in this section deal with the difficult problems of measuring upper winds and upper air temperatures over the sea.

The second section on General Meteorology, which forms more than half the book, is very good. The text is clear, concise and thorough, the illustrations helpful and the mathematics rarely overdone. The simple dynamical treatment in the chapter on wind is especially satisfactory. There is a valuable glossary of local winds and the descriptions of sky types in tropical regions form an unusual but welcome feature. The short chapter on Optical Phenomena, which for some reason is not illustrated, would have been improved by a diagram of

the various types of halo; incidentally it is strange to find " atmospherics " in this company. The last section, on Synoptic Meteorology, is mostly up-to-date, with the modern developments of air-mass and frontal analysis applied to various parts of the world; upper air data as aids to forecasting are also described in some detail.

The book contains no fewer than 167 illustrations, many of them full page plates. There are a few slips, for example in fig. 7 the wet-bulb thermometer reads higher than the dry-bulb and the neck of the water-vessel is non-existent rather than small, but such blemishes are rare and on the whole naval meteorologists could not have asked for a better text-book from the author*, who remains strictly anonymous.

C. E. P. B.

*Aeronautical Meterology*, by George F. Taylor, Ph.D. London: Sir Isaac Pitman & Son, Ltd. 9 × $5\frac{3}{4}$, pp. XVII + 430 *illus.*, price 18*s. net.*

Under the name " Aeronautical Meterology " or some such title, the story of the progress of Meteorology since she entered the service of her flourishing master Aviation, has been told a dozen times in recent years and in at least five languages. Inevitably one compares Dr. Taylor's latest contribution with its predecessors, and particularly with the well known volume by Dr. Byers† with which it has a great deal in common. It is especially interesting to note the echo in the introduction. The earlier volume was " intended for airline pilots and students of meteorology . . . . from the practical point of view "; Dr. Taylor, we find, " has attempted to write a thoroughly practical book that may be used by the

* It is understood that this book was written by Dr. A. G. Forsdyke, of the Naval Meteorological Branch, Admiralty, in collaboration with Naval Meteorological Officers.

† " Synoptic and Aeronautical Meteorology," by Horace R. Byers, Sc.D., McGraw Hill Publishing Co. Ltd., 1937, 21*s.* net, Review: *Met. Mag.*, 1938, page 20, by C. K. M. Douglas.

airline pilot, as well as by the general student of meteorology ". Such an object has its difficulties, for, unless the pilot is expected to be of necessity an expert meteorologist, any attempt to supply the needs of the two professions implies a compromise, with the danger that neither will find quite what it wants. Dr. Taylor has succeeded in his task better than one might think possible but it is only fair to point out that the meteorologist will find some of the treatment too cursory to be of much value (as for example the chapters on Observational Material, the Weather Chart, Weather Chart Analysis and Climatology) while the average pilot will find some heavy going amongst the technicalities of Rossby and Refsdal diagrams, thetagrams and tephigrams, Bjerknes solenoids and Ekmans Spiral, Petterssen's computations and so on. Although the author attempts to reduce these to elementary form the trained scientific mind is apt to forget that the pilot is a busy, practical man with, as a rule, no natural leaning towards abstract thinking. As meteorological instructor and examiner to air pilots, the reviewer has come up against some severe criticism of the sort of meteorological knowledge required of a pilot. We are accused of impressing him more with the abstruseness of our subject than with its practical importance to himself so that many a keen beginner is frightened away at the start. As a reference book in the aeronautical library Dr. Taylor's work should certainly find a place, but as a textbook for the pilot it cannot, with a clear conscience, be very strongly recommended.

Every aviation meteorologist must, however, make a point of reading it. Naturally there is a geographical bias which detracts from its immediate usefulness in England but in the present state of our science we have all much to learn from practice in other countries. The thorough treatment of air-mass analysis is really impressive. Dr. Taylor lists 16 types of air-mass for North America and gives each detailed attention—nothing at all comparable is available for this side of the Atlantic. The author follows Byers in devoting a chapter headed " Forecasting " almost exclusively to

Petterssen's methods of making extrapolations on the field of pressure. On the basis of investigations made on these methods in England they would hardly justify such prominence and one wonders whether their formal attractiveness to the text-book writer, lending a welcome air of mathematical respectability to the wizardry of forecasting, rather outweighs their practical limitations. One feels that the discussion of a few actual synoptic charts (not one is given), might have had as strong a claim to space, particularly for the general reader.

A great feature, which gives the work an atmosphere of its own, are the frequent startling statements on matters of theory which bring the reader up with a salutary jerk. The following, selected from a large number, will serve to illustrate. On p. 80 we are told that without friction " no circulation could exist " in the atmosphere. On p. 227: " it is generally only in regions where weather reports are scanty that the bent-back occlusion survives careful scrutiny!" On p. 282: " only rarely does fog form below freezing point because the heat of fusion retards the cooling process greatly " and lastly, on p. 294: " convergence is generally due to the retardation of a front due to frontogenesis or cyclogenesis ". Such remarks, taken in their context, may be regarded sometimes as shrewd, sometimes as intriguing and sometimes as positively annoying, according to taste, but they are always provoking and stimulating.

Finally a human note. In Dr. Taylor's words " a man who is a poor ' mixer ' will rarely be successful in airline meteorology, no matter how skilled he may be in technical knowledge ". In serving her new-rich master, Meteorology has sold her aristocratic scientific soul to the devil. Meteorological Services might usefully note this clause in their contract, but it would be unwise to infer that social accomplishments will altogether obscure technical blundering. Aviation is, outside the Club or Officers' Mess, a hard master.

R. C. SUTCLIFFE.

## Daily Readings at Kew Observatory, April 1939

| Date. | Pressure, M.S.L. 13h. | Wind, Dir. | Force 13h. | Temp. Min. | Temp. Max. | Rel. Hum. 13h. | Rain. | Sun. | Remarks. |
|---|---|---|---|---|---|---|---|---|---|
| | mb. | | | °F. | °F. | % | in. | hrs. | |
| 1 | 1010·4 | SSE | 2 | 38 | 57 | 69 | 0·06 | 0·0 | f 5h–12h, $r_0$ 19h– |
| **2** | 1002·6 | SW | 3 | 47 | 52 | 87 | 0·43 | 0·0 | r 2h–6h, R 4h. [23h. |
| 3 | 995·2 | SSE | 4 | 35 | 48 | 85 | 0·07 | 0·0 | $pr_0$ 17h, $r_0$ 21h–24h. |
| 4 | 986·3 | SW | 3 | 47 | 54 | 86 | 0·26 | 2·1 | $ir_0$–r 0h–3h & 11h–13h. |
| 5 | 996·3 | S | 4 | 46 | 55 | 80 | 0·20 | 2·1 | R 10h, $r_0$ 21 h–22h. |
| 6 | 1009·2 | NE | 4 | 40 | 46 | 73 | 0·15 | 0·0 | $r_0$–r 3h–8h, $ir_0$ 8h–10h. |
| 7 | 1018·5 | E | 3 | 38 | 49 | 58 | — | 3·8 | |
| 8 | 1018·2 | SW | 2 | 32 | 54 | 62 | — | 9·7 | |
| **9** | 1017·0 | SSW | 1 | 37 | 62 | 54 | — | 11·1 | |
| 10 | 1014·0 | ENE | 4 | 43 | 64 | 52 | — | 7·7 | |
| 11 | 1012·3 | ENE | 3 | 46 | 72 | 51 | — | 10·3 | |
| 12 | 1016·1 | SW | 4 | 44 | 69 | 56 | — | 10·1 | f 7h. |
| 13 | 1013·1 | SSW | 5 | 49 | 60 | 69 | 0·02 | 3·4 | $r_0$ 18h–20h. |
| 14 | 1006·0 | SW | 3 | 49 | 59 | 88 | 0·01 | 2·7 | $pr_0$ 11h, 18h & 20h. |
| 15 | 1016·1 | SW | 3 | 45 | 57 | 55 | trace | 4·4 | $pr_0$ 15h & 16h. |
| **16** | 1017·1 | WSW | 4 | 53 | 61 | 76 | trace | 3·0 | $pr_0$ 9h. & 10h. |
| 17 | 1017·4 | W | 5 | 47 | 57 | 49 | 0·02 | 8·0 | $r_0$ 2h–3h, $pr_0$ 13h. |
| 18 | 1035·5 | NNE | 4 | 41 | 54 | 57 | 0·01 | 12·0 | $r_0$ 1h–2h. |
| 19 | 1036·4 | NW | 2 | 39 | 63 | 52 | — | 11·8 | |
| 20 | 1030·7 | W | 2 | 42 | 68 | 42 | — | 12·0 | |
| 21 | 1024·5 | SW | 3 | 43 | 67 | 32 | — | 10·4 | |
| 22 | 1014·1 | NW | 5 | 46 | 54 | 38 | trace | 8·4 | $pr_0$ 13h, 17h & 21h. |
| **23** | 1009·8 | W | 3 | 43 | 52 | 76 | 0·04 | 0·8 | $r_0$ 9h–13h & 21h–24h. |
| 24 | 996·0 | WNW | 4 | 48 | 55 | 60 | 0·14 | 5·7 | $r_0$ 5h–9h, t rh 12h. |
| 25 | 1003·1 | N | 3 | 38 | 51 | 62 | — | 8·3 | |
| 26 | 1013·6 | N | 4 | 35 | 49 | 60 | trace | 6·6 | $pr_0$ 13h, 14h & 17h. |
| 27 | 1023·8 | N | 3 | 35 | 49 | 74 | 0·09 | 9·6 | prh 12h, pRh 18h. |
| 28 | 1024·3 | NNE | 2 | 35 | 51 | 49 | 0·15 | 7·3 | rh–R 18h–19h. |
| 29 | 1021·9 | NNE | 4 | 37 | 50 | 63 | 0·07 | 2·9 | $pr_0$ 16h, $r_0$ 17h–22h. |
| **30** | 1014·9 | NNE | 3 | 41 | 45 | 88 | 0·49 | 0·0 | $r_0$–r 5h–13h & 15h–24h. |
| * | 1013·8 | — | | 42 | 56 | 63 | 2·21 | 5·8 | *Means or Totals |

## General Rainfall for April 1939

| | Per cent. |
|---|---|
| England and Wales .. .. .. | 125 |
| Scotland .. .. .. .. .. | 81 |
| Ireland .. .. .. .. .. | 76 |
| British Isles .. .. .. | 104 |

## Rainfall: April, 1939: England and Wales

| Co. | Station. | In. | Per cent of Av. | Co. | Station. | In. | Per cent of Av. |
|---|---|---|---|---|---|---|---|
| *Lond* . | Camden Square..... | 2·58 | 168 | *War* . | Birminghm, Edgbaston | 2·11 | 121 |
| *Sur* . | Reigate, Wray Pk. Rd. | 2·99 | 179 | *Leics* . | Thornton Reservoir... | 1·83 | 108 |
| *Kent* . | Tenterden, Ashenden. | 2·21 | 136 | ,, . | Belvoir Castle..... | 2·16 | 141 |
| ,, . | Folkestone, I. Hospital | 3·09 | .. | *Rut* . | Ridlington ..... | 2·22 | 141 |
| ,, . | Margate, Cliftonville.. | 2·31 | 171 | *Lincs* . | Boston, Skirbeck..... | 2·05 | 152 |
| ,, . | Eden'bdg.,Falconhurst | 2·37 | 127 | ,, . | Cranwell Aerodrome.. | 1·85 | 140 |
| *Sus* . | Compton, Compton Ho | 2·77 | 138 | ,, . | Skegness, Marine Gdns | 2·09 | 156 |
| ,, . | Patching Farm..... | 2·93 | 167 | ,, . | Louth, Westgate..... | 2·48 | 148 |
| ,, . | Eastbourne, Wil. Sq.. | 2·11 | 116 | ,, . | Brigg, Wrawby St.... | 1·74 | .. |
| *Hants* . | Ventnor, Roy.Nat.Hos. | 3·04 | 181 | *Notts* . | Mansfield, Carr Bank.. | 1·55 | 90 |
| ,, . | Southampton, East Pk | 2·15 | 116 | *Derby* . | Derby, The Arboretum | 1·63 | 96 |
| ,, . | Ovington Rectory.... | 2·15 | 114 | ,, . | Buxton, Terrace Slopes | 2·84 | 97 |
| ,, . | Sherborne St. John... | 2·77 | 156 | *Ches* . | Bidston Obsy..... | 2·02 | 124 |
| *Herts* . | Royston, Therfield Rec | 3·06 | 195 | *Lancs* . | Manchester, Whit. Pk. | 2·13 | 111 |
| *Bucks* . | Slough, Upton..... | 2·66 | 186 | ,, . | Stonyhurst College... | 2·23 | 82 |
| *Oxf* . | Oxford, Radcliffe..... | 3·02 | 189 | ,, . | Southport, Bedford Pk | 2·08 | 112 |
| *N'hant* | Wellingboro,Swanspool | 1·92 | 129 | ,, . | Ulverston, Poaka Beck | 2·26 | 75 |
| ,, . | Oundle ..... | 2·28 | .. | ,, . | Lancaster, Greg Obsy. | 2·49 | 111 |
| *Beds* . | Woburn, Exptl. Farm. | 3·41 | 227 | ,, . | Blackpool ..... | 2·51 | 134 |
| *Cam* . | Cambridge, Bot. Gdns. | 2·81 | 207 | *Yorks* . | Wath-upon-Dearne... | 1·29 | 82 |
| ,, . | March ..... | 1·85 | 140 | ,, . | Wakefield,Clarence Pk. | 1·26 | 75 |
| *Essex* . | Chelmsford,CountyGns | 3·45 | 270 | ,, . | Oughtershaw Hall.... | 3·30 | .. |
| ,, . | Lexden Hill House.... | 2·48 | .. | ,, . | Wetherby, Ribston H. | 1·21 | 69 |
| *Suff* . | Haughley House..... | 2·12 | .. | ,, . | Hull, Pearson Park... | 1·37 | 88 |
| ,, . | Rendlesham Hall..... | .. | .. | ,, . | Holme-on-Spalding... | 1·16 | 70 |
| ,, . | Lowestoft Sec. School. | 2·46 | 166 | ,, . | Felixkirk, Mt. St. John | 1·07 | 64 |
| ,, . | Bury St. Ed.,WestleyH | 2·89 | 189 | ,, . | York, Museum ..... | 1·28 | 80 |
| *Norf* . | Wells, Holkham Hall. | 2·58 | 202 | ,, . | Pickering, Houndgate. | 1·26 | 75 |
| *Wilts* . | Porton, W.D. Exp'lStn | 2·45 | 147 | ,, . | Scarborough..... | 1·72 | 110 |
| ,, . | Bishops Cannings .... | 3·65 | 181 | ,, . | Middlesbrough..... | 1·19 | 87 |
| *Dor* . | Weymouth, Westham. | 2·11 | 127 | ,, . | Baldersdale, Hury Res. | 1·95 | 81 |
| ,, . | Beaminster, East St .. | 2·72 | 115 | *Durh* . | Ushaw College..... | 1·04 | 55 |
| ,, . | Shaftesbury ..... | 2·14 | .. | *Nor* . | Newcastle, Leazes Pk. | ·99 | 62 |
| *Devon* . | Plymouth, The Hoe... | 2·79 | 123 | ,, . | Bellingham, Highgreen | 2·60 | 120 |
| ,, . | Holne, Church Pk.Cott | 4·99 | 138 | ,, . | Lilburn Tower Gdns.. | 1·36 | 69 |
| ,, . | Teignmouth, Den Gdns | 2·33 | 116 | *Cumb* . | Carlisle, Scaleby Hall. | 1·32 | 68 |
| ,, . | Cullompton ..... | 2·58 | 114 | ,, . | Borrowdale,Seathwaite | 7·50 | 109 |
| ,, . | Sidmouth, U.D.C..... | 2·16 | .. | ,, . | Thirlmere,DaleHeadH. | 3·96 | 81 |
| ,, . | Barnstaple,N. Dev.Ath | 2·35 | 111 | ,, . | Keswick, High Hill... | 2·94 | 96 |
| ,, . | Dartm'r,Cranmere P'l | 5·80 | .. | ,, . | Ravenglass, The Grove | 2·25 | 91 |
| ,, . | Okehampton, Uplands. | 4·74 | 149 | *West* . | Appleby, Castle Bank. | 1·20 | 62 |
| *Corn* . | Redruth, Trewirgie... | 3·66 | 127 | *Mon* . | Abergavenny, Larchf'd | 3·07 | 121 |
| ,, . | Penzance, MorrabGdns | 3·48 | 143 | *Glam* . | Ystalyfera, Wern Ho.. | 5·17 | 163 |
| ,, . | St. Austell, Trevarna.. | 3·84 | 136 | ,, . | Treherbert, Tynywaun | 7·20 | .. |
| *Soms* . | Chewton Mendip..... | 4·33 | 146 | ,, . | Cardiff, Penylan..... | 3·37 | 135 |
| ,, . | Long Ashton ..... | 3·27 | 150 | *Carm* . | Carmarthen,M.&P.Sc. | 3·79 | 133 |
| ,, . | Street, Millfield ..... | 2·61 | 133 | *Card* . | Aberystwyth ..... | 1·93 | .. |
| *Glos* . | Blockley ..... | 2·95 | .. | *Rad* . | Bir. W. W. Tyrmynydd | 4·62 | 125 |
| ,, . | Cirencester, Gwynfa .. | 4·01 | 214 | *Mont* . | Lake Vyrnwy..... | 3·45 | 115 |
| *Here* . | Ross-on-Wye ..... | 2·54 | 134 | *Flint* . | Sealand Aerodrome... | 1·90 | 131 |
| ,, . | Kington, Lynhales.... | 1·96 | 99 | *Mer* . | Blaenau Festiniog.... | 5·90 | 106 |
| *Salop* . | Church Stretton..... | 2·76 | .. | ,, . | Dolgelley, Bontddu... | 3·25 | 89 |
| ,, . | Shifnal, Hatton Grange | 1·53 | 91 | *Carn* . | Llandudno ..... | 1·91 | 113 |
| ,, . | Cheswardine Hall .... | 1·84 | 105 | ,, . | Snowdon, L. Llydaw 9 | 8·25 | .. |
| *Worc* . | Malvern, Free Library. | 2·35 | 131 | *Ang* . | Holyhead, Salt Island. | 1·90 | 91 |
| ,, . | Ombersley, Holt Lock. | 1·78 | 117 | ,, . | Lligwy..... | 1·87 | .. |
| *War* . | Alcester, Ragley Hall. | 2·03 | 120 | *I.Man* | Douglas, Boro' Cem... | 2·31 | 95 |

ERRATUM: Middlesbrough, March, *for* 2.03/129 *read* 2·08/132.

## Rainfall: April, 1939: Scotland and Ireland

| Co. | Station. | In. | Per cent of Av. | Co. | Station. | In. | Per cent of Av. |
|---|---|---|---|---|---|---|---|
| *Guern.* | St.PeterP't.GrangeRd. | 1·89 | 94 | *R&C.* | Stornoway, C.G.Stn... | 2·57 | 89 |
| *Wig .* | Pt. William, Monreith. | 1·69 | 77 | *Suth .* | Lairg ..... | 2·32 | 100 |
| ,, . | New Luce School..... | 2·09 | 79 | ,, . | Skerray Borgie..... | 1·97 | .. |
| *Kirk .* | Dalry, Glendarroch... | 2·29 | 75 | ,, . | Melvich ..... | 1·55 | 67 |
| *Dumf.* | Eskdalemuir Obs..... | 2·47 | 73 | ,, . | Loch More, Achfary.. | 4·07 | 84 |
| *Roxb .* | Hawick, Wolfelee .... | 1·11 | 49 | *Caith .* | Wick ..... | ·99 | 50 |
| ,, . | Kelso, Broomlands.... | 1·01 | 64 | *Ork .* | Deerness ..... | 1·52 | 73 |
| *Peeb .* | Stobo Castle..... | .. | .. | *Shet .* | Lerwick Observatory. | 2·70 | 118 |
| *Berw .* | Marchmont House.... | 1·57 | 78 | *Cork .* | Cork, University Coll. | 2·08 | 79 |
| *E.Lot.* | North Berwick Res... | ·85 | 61 | ,, . | Roches Point, C.G.Stn. | 1·91 | 71 |
| *Midl .* | Edinburgh, Blackfd. H | 1·18 | 80 | ,, . | Mallow, Waterloo.... | 1·69 | 69 |
| *Lan .* | Auchtyfardle ..... | 1·67 | .. | *Kerry.* | Valentia Observatory. | 2·26 | 62 |
| *Ayr .* | Kilmarnock, Kay Park | 2·22 | .. | ,, . | Gearhameen..... | 4·10 | 71 |
| ,, . | Girvan, Pinmore ..... | 2·32 | 78 | ,, . | Bally McElligott Rec. | 1·11 | .. |
| ,, . | Glen Afton, Ayr San.. | 3·31 | 110 | ,, . | Darrynane Abbey.... | 1·81 | 53 |
| *Renf .* | Glasgow, Queen's Park | 1·71 | 87 | *Wat .* | Waterford, Gortmore. | 1·18 | 47 |
| ,, . | Greenock, Prospect H. | 3·66 | 106 | *Tip .* | Nenagh, Castle Lough. | 1·21 | 48 |
| *Bute .* | Rothesay, Ardencraig. | 3·06 | 103 | ,, . | Cashel, Ballinamona.. | 1·45 | 59 |
| ,, | Dougarie Lodge..... | 2·10 | 74 | *Lim .* | Foynes, Coolnanes.... | 1·24 | 51 |
| *Arg .* | Loch Sunart, G'dale.. | .. | .. | ,, . | Limerick, Mulgrave St. | 1·66 | 69 |
| ,, | Ardgour House ..... | 4·97 | .. | *Clare .* | Inagh, Mount Callan.. | 2·70 | .. |
| ,, | Glen Etive ..... | 5·54 | 100 | *Wexf .* | Gorey, Courtown Ho.. | 1·84 | 84 |
| ,, | Oban ..... | 2·57 | .. | *Wick .* | Rathnew, Clonmannon | 1·31 | .. |
| ,, | Poltalloch ..... | 2·70 | 89 | *Carl .* | Bagnalstown FenaghH | 1·57 | 69 |
| ,, | Inveraray Castle .... | 4·34 | 94 | ,, . | Hacketstown Rectory. | 1·63 | 62 |
| ,, | Islay, Eallabus ..... | 1·62 | 56 | *Leix .* | Blandsfort House .... | 2·19 | 84 |
| ,, . | Mull, Benmore..... | 3·75 | 48 | *Offaly.* | Birr Castle ..... | 1·08 | 50 |
| ,, | Tiree ..... | .. | .. | *Kild .* | Straffan House..... | .. | .. |
| *Kinr .* | Loch Leven Sluice.... | 1·49 | 78 | *Dublin* | Dublin, Phoenix Park. | 2·04 | 113 |
| *Fife .* | Leuchars Aerodrome.. | ·88 | 55 | *Meath.* | Kells, Headfort..... | 2·05 | 82 |
| *Perth .* | Loch Dhu ..... | 3·95 | 83 | *W.M .* | Moate, Coolatore..... | 1·83 | .. |
| ,, . | Crieff, Strathearn Hyd. | 1·83 | 84 | ,, . | Mullingar, Belvedere.. | .. | .. |
| ,, . | Blair Castle Gardens.. | 1·78 | 84 | *Long .* | Castle Forbes Gdns .. | 1·98 | 83 |
| *Angus.* | Kettins School..... | 1·09 | 60 | *Gal .* | Galway, Grammar Sch. | 1·46 | 62 |
| ,, . | Pearsie House ..... | 1·17 | .. | ,, . | Ballynahinch Castle .. | 3·58 | 101 |
| ,, . | Montrose, Sunnyside.. | ·61 | 34 | ,, . | Ahascragh, Clonbrock. | 1·78 | 70 |
| *Aber .* | Balmoral Castle Gdns. | 1·21 | 56 | *Rosc .* | Strokestown, C'node.. | 1·49 | 68 |
| ,, . | Logie Coldstone Sch .. | 1·14 | 57 | *Mayo.* | Blacksod Point ..... | 2·34 | 81 |
| ,, . | Aberdeen Observatory. | ·84 | 45 | ,, . | Mallaranny..... | 3·29 | .. |
| ,, . | New Deer SchoolHouse | 1·62 | 81 | ,, . | Westport House..... | 1·63 | 60 |
| *Moray* | Gordon Castle ..... | 1·38 | 79 | ,, . | Delphi Lodge..... | 5.45 | 95 |
| ,, . | Grantown-on-Spey ... | 1·73 | 88 | *Sligo .* | Markree Castle..... | 1·77 | 67 |
| *Nairn.* | Nairn..... | 1·17 | 78 | *Cavan.* | Crossdoney, Kevit Cas. | 1·59 | .. |
| *Inv's .* | Ben Alder Lodge..... | 2·37 | .. | *Ferm .* | Crom Castle ..... | 1·96 | 77 |
| ,, . | Kingussie, The Birches | 1·67 | .. | *Arm .* | Armagh Obsy..... | 2·39 | 114 |
| ,, . | Loch Ness, Foyers.... | 2·27 | 105 | *Down.* | Fofanny Reservoir .... | 4·50 | .. |
| ,, . | Inverness, Culduthel R | 1·16 | 70 | ,, . | Seaforde ..... | 2·28 | 87 |
| ,, . | Loch Quoich, Loan... | 7·65 | .. | ,, . | Donaghadee, C. G. Stn. | 1·80 | 90 |
| ,, . | Glenquoich ..... | 6·52 | 100 | *Antr .* | Belfast,Queen's Univ . | 2·46 | 110 |
| ,, . | Arisaig House ..... | 3·73 | 104 | ,, . | Aldergrove Aerodrome | 2·18 | 103 |
| ,, . | Glenleven, Corrour ... | 4·53 | 111 | ,, . | Ballymena, Harryville. | 2·33 | 88 |
| ,, . | Ft. William, Glasdrum | 3·38 | .. | *Lon .* | Garvagh, Moneydig... | 2·20 | .. |
| ,, . | Skye, Dunvegan ..... | 3·43 | .. | ,, . | Londonderry, Creggan. | 1·82 | 71 |
| ,, . | Barra, Skallary ..... | .. | .. | *Tyr .* | Omagh, Edenfel..... | 2·46 | 94 |
| *R&C.* | Tain, Ardlarach..... | 2·28 | 116 | *Don .* | Malin Head..... | 1·69 | 70 |
| ,, . | Ullapool ..... | 2·85 | 92 | ,, . | Dunfanaghy ..... | 1·44 | 62 |
| ,, . | Achnashellach ..... | 6·79 | 120 | ,, . | Dunkineely..... | 1·58 | .. |

# Climatological Table for the British Empire, November 1938

| STATIONS. | PRESSURE. | | TEMPERATURE. | | | | | | | Relative Humidity. | Mean Cloud Am'nt | PRECIPITATION. | | | BRIGHT SUNSHINE. | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | Absolute. | | Mean Values. | | | | Mean. | | | | | | | |
| | Mean of Day M.S.L. | Diff. from Normal. | Max. | Min. | Max. | Min. | ½ Max. and Min. | Diff. from Normal. | Wet Bulb. | | | Am'nt. | Diff. from Normal. | Days. | Hours per day. | Percentage of possible. |
| | mb. | mb. | °F. | °F. | °F. | °F. | °F. | °F. | °F. | % | 0–10 | in. | in. | | | |
| London, Kew Obsy... | 1011·1 | − 3·5 | 66 | 32 | 54·5 | 45·0 | 49·7 | + 6·2 | 47·0 | 90 | 8·4 | 2·60 | + 0·38 | 17 | 2·1 | 23 |
| Gibraltar..... | 1021·0 | + 3·0 | 69 | 49 | 65·6 | 57·0 | 61·3 | + 1·3 | 56·3 | 83 | 5·3 | 0·86 | — | 7 | — | — |
| Malta..... | 1019·3 | + 3·4 | 70 | 52 | 67·5 | 59·6 | 63·5 | − 0·4 | 58·7 | 78 | 6·0 | 4·20 | + 0·63 | 12 | 6·1 | 60 |
| St. Helena ..... | 1017·2 | − 0·4 | 75 | 52 | 62·1 | 54·2 | 58·1 | − 0·4 | 55·1 | 89 | 9·2 | 0·84 | − 0·34 | 11 | — | — |
| Freetown, Sierra Leone | 1011·7 | + 2·5 | 90 | 72 | 86·3 | 74·4 | 80·3 | — | 73·6 | 91 | 7·4 | 5·10 | − 0·02 | 18 | — | — |
| Lagos, Nigeria ..... | 1010·3 | + 0·2 | 89 | 69 | 85·5 | 72·6 | 79·1 | − 2·6 | 76·0 | 90 | 7·2 | 6·24 | + 3·57 | 12 | 6·3 | 53 |
| Kaduna, Nigeria ..... | 1009·8 | — | 95 | 57 | 91·6 | 62·4 | 77·0 | − 0·9 | 64·8 | 51 | 3·6 | 0·00 | − 0·21 | 0 | 9·5 | 82 |
| Zomba, Nyasaland.... | 1008·9 | 0·0 | 94 | 55 | 84·9 | 65·7 | 75·3 | − 0·3 | 68·6 | 69 | 6·4 | 1·73 | − 3·35 | 3 | — | — |
| Salisbury, Rhodesia .. | 1010·9 | − 0·1 | 91 | 50 | 80·3 | 58·0 | 69·1 | − 1·6 | 59·5 | 54 | 5·9 | 3·41 | — | 11 | 6·8 | 53 |
| Cape Town ..... | 1017·2 | + 1·4 | 93 | 45 | 74·8 | 54·3 | 64·5 | + 0·1 | 57·8 | 66 | 4·5 | 0·93 | − 0·16 | 8 | — | — |
| Johannesburg ..... | 1012·1 | + 0·7 | 88 | 34 | 77·1 | 53·1 | 65·1 | + 1·4 | 52·7 | 49 | 4·0 | 1·02 | − 3·94 | 9 | 8·9 | 66 |
| Mauritius ..... | 1017·8 | + 1·7 | 85 | 62 | 82·2 | 66·9 | 74·6 | − 0·9 | 68·4 | 62 | 5·4 | 0·77 | − 0·99 | 18 | 8·7 | 67 |
| Calcutta, Alipore Obsy. | 1012·9 | − 0·4 | 88 | 57 | 83·8 | 63·9 | 73·9 | + 0·4 | 65·7 | 82 | 3·1 | 0·11 | − 0·54 | 0* | — | — |
| Bombay ..... | 1011·9 | − 0·1 | 92 | 65 | 86·0 | 70·3 | 78·1 | − 2·5 | 68·6 | 71 | 1·9 | 1·13 | + 0·68 | 1* | — | — |
| Madras ..... | 1011·5 | + 0·2 | 90 | 64 | 85·9 | 70·6 | 78·3 | − 0·6 | 71·7 | 76 | 5·7 | 0·25 | −13·36 | 1* | — | — |
| Colombo, Ceylon ..... | 1011·3 | + 1·3 | 90 | 67 | 86·3 | 73·1 | 79·7 | − 0·3 | 74·7 | 69 | 4·8 | 3·82 | − 7·94 | 7 | 8·7 | 74 |
| Singapore ..... | 1009·5 | + 0·1 | 89 | 71 | 85·9 | 74·5 | 80·2 | − 0·4 | 77·2 | 79 | 8·5 | 6·44 | − 3·47 | 20 | 4·6 | 38 |
| Hongkong..... | 1017·9 | + 0·3 | 81 | 57 | 74·2 | 65·7 | 69·9 | + 0·3 | 61·8 | 62 | 6·6 | 0·53 | − 1·21 | 3 | 5·2 | 47 |
| Sandakan ..... | 1008·3 | — | 89 | 72 | 85·7 | 74·5 | 80·1 | − 0·8 | 77·1 | 88 | 8·9 | 22·78 | + 8·06 | 24 | — | — |
| Sydney, N.S.W..... | 1013·1 | − 0·7 | 95 | 57 | 75·9 | 62·8 | 69·3 | + 2·3 | 64·3 | 66 | 7·2 | 1·73 | − 1·12 | 14 | 7·1 | 51 |
| Melbourne ..... | 1013·4 | − 1·0 | 99 | 45 | 75·8 | 52·4 | 64·1 | + 2·8 | 56·6 | 50 | 6·1 | 1·47 | − 0·76 | 11 | 7·3 | 52 |
| Adelaide ..... | 1014·2 | − 1·1 | 102 | 47 | 82·5 | 55·7 | 69·1 | + 2·1 | 58·0 | 36 | 5·2 | 0·50 | − 0·64 | 6 | 9·4 | 68 |
| Perth, W. Australia.... | 1013·4 | − 2·0 | 98 | 47 | 76·0 | 57·4 | 66·7 | + 0·6 | 59·8 | 55 | 5·7 | 1·79 | + 0·99 | 5 | 9·6 | 70 |
| Coolgardie ..... | 1011·5 | − 1·9 | 108 | 41 | 86·9 | 59·2 | 73·1 | + 2·4 | 61·8 | 54 | 2·0 | 0·39 | − 0·30 | 1 | — | — |
| Brisbane ..... | 1013·6 | − 1·0 | 94 | 62 | 81·3 | 66·2 | 73·7 | + 0·2 | 68·0 | 68 | 6·8 | 4·76 | + 1·03 | 13 | 7·4 | 58 |
| Hobart, Tasmania.... | 1011·3 | + 1·7 | 92 | 44 | 66·6 | 49·2 | 57·9 | + 0·7 | 54·2 | 62 | 7·0 | 2·24 | − 0·23 | 14 | 6·4 | 44 |
| Wellington, N.Z..... | 1015·2 | + 3·1 | 71 | 44 | 64·4 | 50·5 | 57·5 | + 0·7 | 55·2 | 76 | 8·1 | 1·99 | − 1·53 | 14 | 6·4 | 44 |
| Suva, Fiji ..... | 1009·2 | − 1·9 | 87 | 71 | 83·8 | 73·3 | 78·5 | + 1·4 | 74·9 | 82 | 7·3 | 20·77 | +10·98 | 22 | 5·2 | 40 |
| Apia, Samoa ..... | 1008·0 | − 1·5 | 87 | 72 | 83·1 | 74·4 | 78·7 | 0·0 | 75·8 | 84 | 8·7 | 33·35 | +23·52 | 29 | 3·3 | 26 |
| Kingston, Jamaica ... | 1011·1 | − 1·3 | 93 | 69 | 88·7 | 71·8 | 80·3 | + 1·0 | 72·1 | 94 | 4·6 | 0·52 | − 2·51 | 4 | 8·1 | 72 |
| Grenada, W.I. ..... | 1013·3 | + 2·7 | 87 | 71 | 85·8 | 72·3 | 79·1 | − 0·4 | 73 | 75 | **7** | 14·45 | + 5·99 | 25 | — | — |
| Toronto..... | 1019·0 | + 1·7 | 69 | 14 | 48·7 | 33·7 | 41·2 | + 4·2 | 35·4 | 81 | 5·9 | 1·45 | − 1·18 | 12 | 3·9 | 40 |
| Winnipeg ..... | 1016·1 | − 1·3 | 53 | −14 | 27·8 | 9·9 | 18·9 | − 2·4 | 15·6 | 74 | 7·4 | 0·86 | − 0·21 | 9 | 2·4 | 26 |
| St. John, N.B. ..... | 1018·6 | + 4·0 | 62 | 10 | 45·6 | 31·5 | 38·5 | + 1·8 | 34·3 | 84 | 6·6 | 4·11 | − 0·30 | 16 | 4·1 | 43 |
| Victoria, B.C..... | 1020·5 | + 4·6 | 55 | 31 | 47·8 | 39·7 | 43·7 | − 0·8 | 41·6 | 84 | 7·3 | 2·96 | − 2·45 | 17 | 3·3 | 35 |

* For Indian stations a rain day is a day on which 0·1 in. or more rain has fallen.

Erratum—Wellington, N.Z. August 1938. Precipitation Diff. from Normal, *for* −2·51 *read* +2·51.

(47163) Wt. 22/31 1,375 5/39 Hw. G.377/6

• For Indian stations a rain day is a day on which 0·1 in. or more rain has fallen.

Erratum—Wellington, N.Z. August 1938, Precipitation Diff. from Normal, *for* −2·51 *read* +2·51.